Aquifer Exemptions for In-Situ Leach Mining

Presented by EPA Region 6

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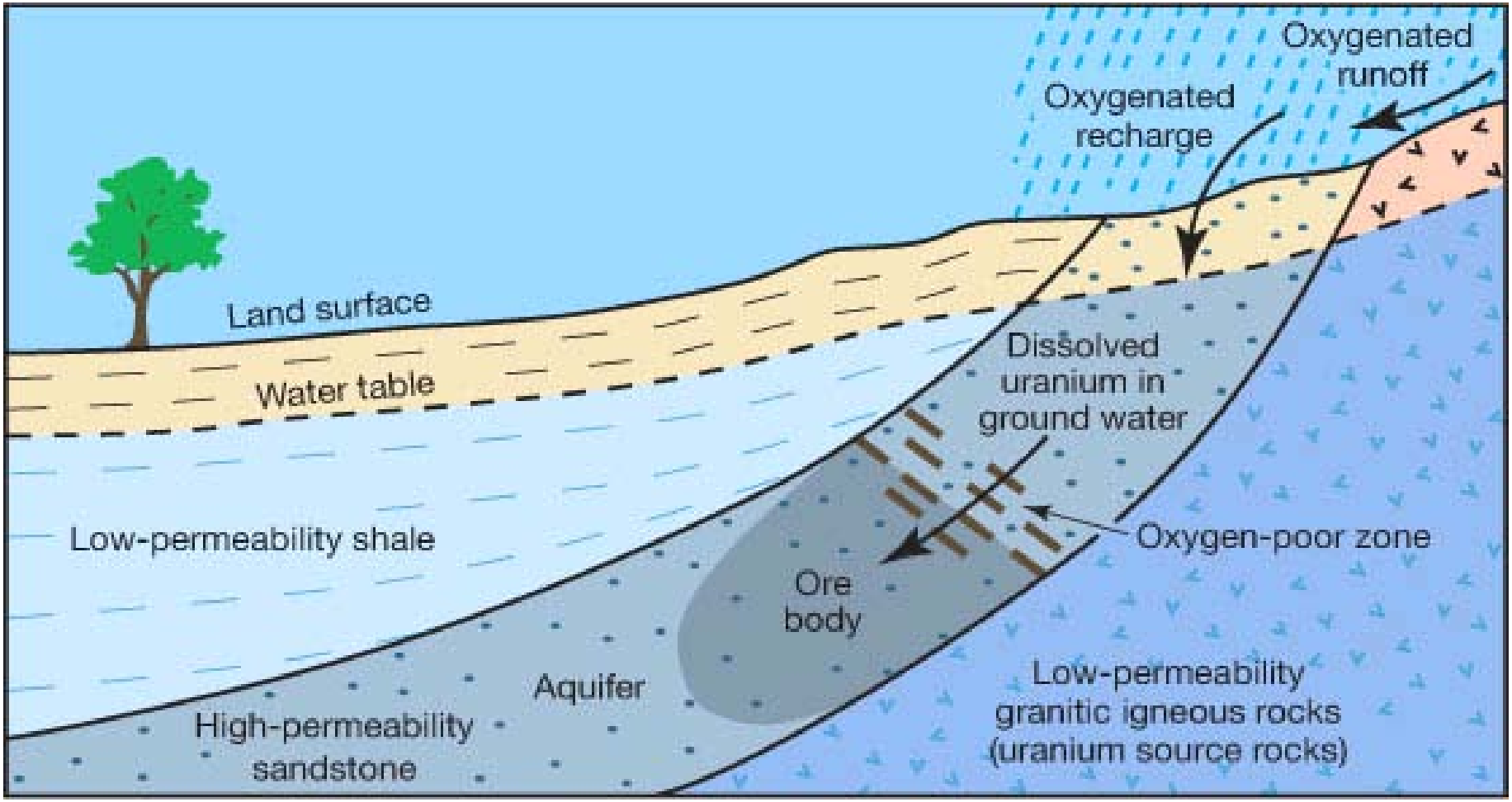
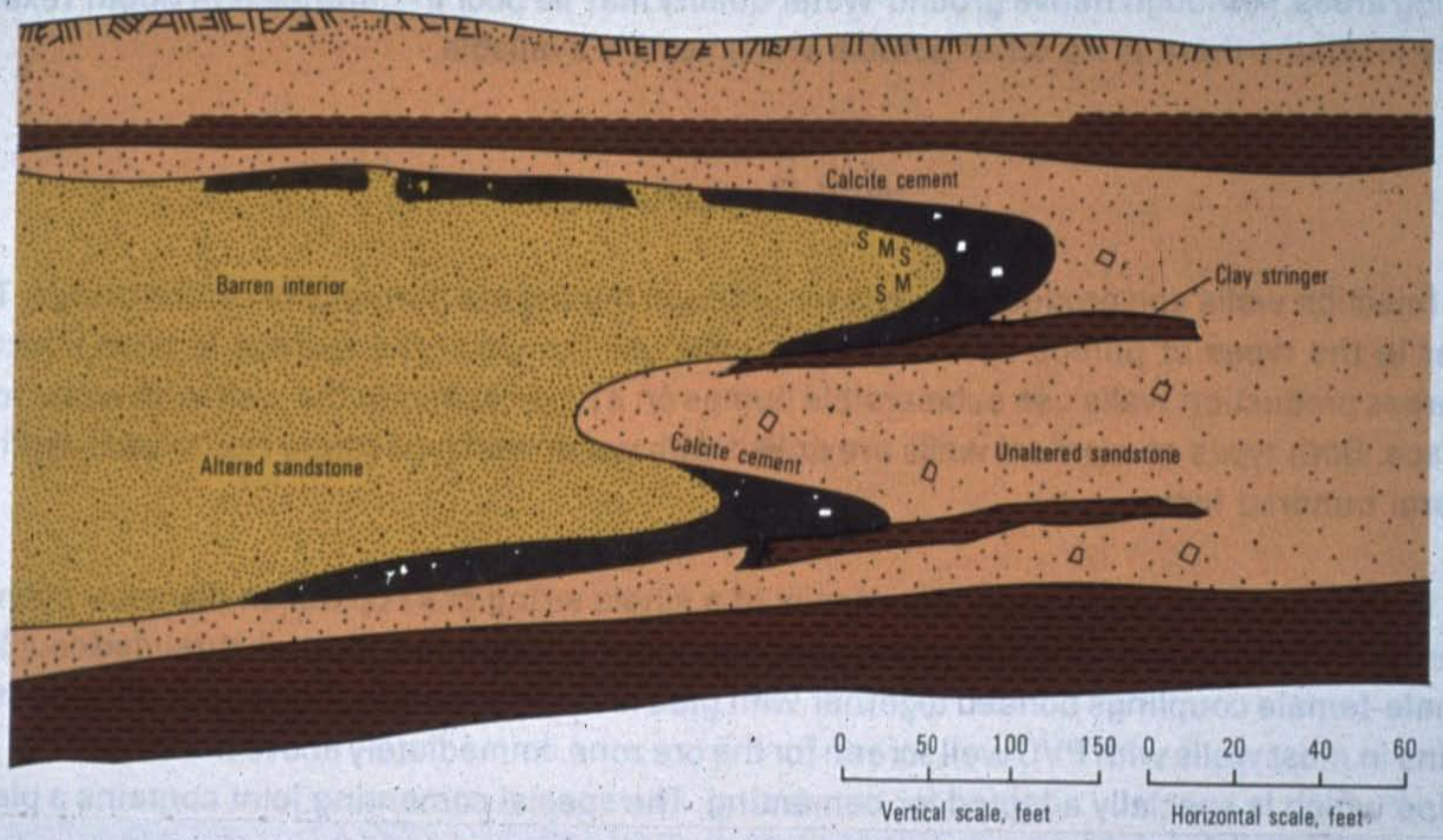
What's involved in an aquifer exemption for in-situ uranium mining?

- Overview of in-situ uranium mining process
- UIC regulations relating to in-situ mining
  - Well class
  - Definitions
- Typical mining site layout
  - Well types
- Defining an aquifer exemption area
- EPA Guidance No. 34

Uranium deposition



IDEALIZED URANIUM ROLL FRONT DEPOSITS



Oxidixed Barren Interior
Unaltered Sandstone
Siltstone or Claystone
Uranium Mineralization

SMS SM — Selenium Molybdenum

Pyrite

ERRATIC

In-situ wellfield with numerous injection and extraction wells

- Uses a network of injection and production wells completed in a subsurface ore zone
- Injects oxygenated water (sometimes with added carbonate) into the ore zone to dissolve uranium
- Pumps the uranium-bearing solution to the land surface for recovery and processing into the product “yellowcake” ($U_3 0_8$)
- Recycles the mining process water back into the ore zone for recovery of more uranium

How in-situ leaching works

- The ISL method involves these steps (diagram of in situ leaching):
- A solution of oxygen, hydrogen peroxide, or another oxidizing agent in water is injected into an underground zone that bears uranium ore.
- In contact with this injection solution, the uranium dissolves.
- The injection solution containing the dissolved uranium is pumped back to the surface to recover it.
- At the surface, the recovered injection solution is passed through an ion-exchange column. The uranium sticks to the ion-exchange column, and a uranium-free solution flows out. With the addition of an oxidizing agent, this solution can be reused as injection solution in step 1.
- A stripping solution is poured through the ion-exchange column to redissolve the uranium.
- The uranium-bearing solution is chemically treated to turn the uranium into a solid form. This uranium-containing solid is isolated and transported elsewhere for further processing.
- As a result, the main impact of ISL is on the characteristics of the porous rock at the depth where the uranium is recovered, the so-called “uranium capture zone.” To monitor and address this impact, the licensee is required to take these steps:

How in-situ leaching works

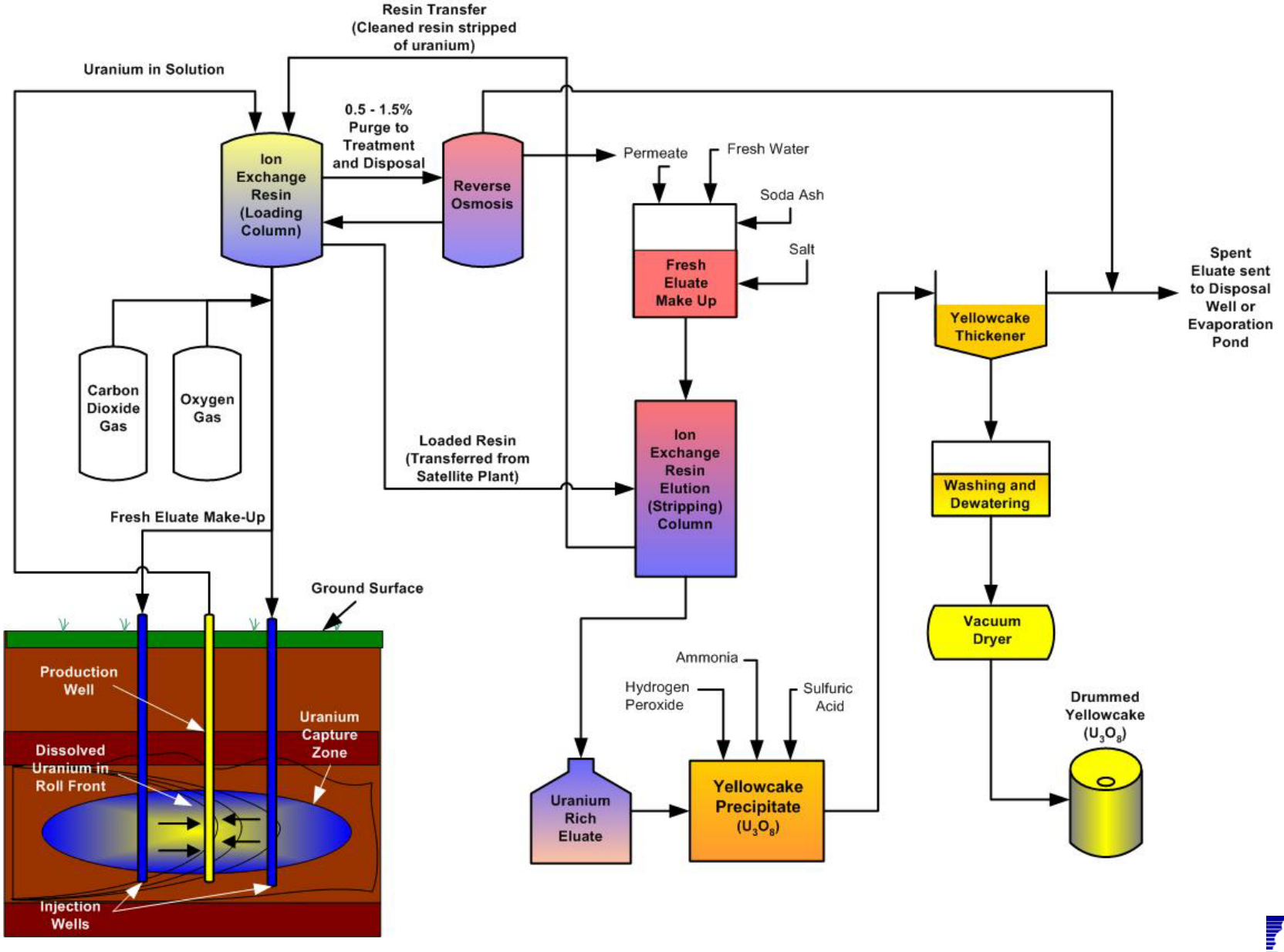
- **Before Exploration begins*:**
  - **Collect baseline ground water data from existing wells before exploration phase**
- **As part of aquifer exemption request***
  - **Describe the methodology for developing the restoration tables**
    - **Identify location of wells where samples were collected**
    - **Are the samples representative of the overall water quality of the aquifer?**
- **Before ISL begins:**
  - **Collect enough environmental data on local air, soil, and ground water to establish a baseline for comparison to later data.**
  - **Drill a set of precisely spaced monitoring wells just outside the uranium capture zone in all directions—around, above, and below.**
  - **Space monitoring wells between the ore body to be mined and the adjacent non exempted USDW.***

*EPA R6 additions in red

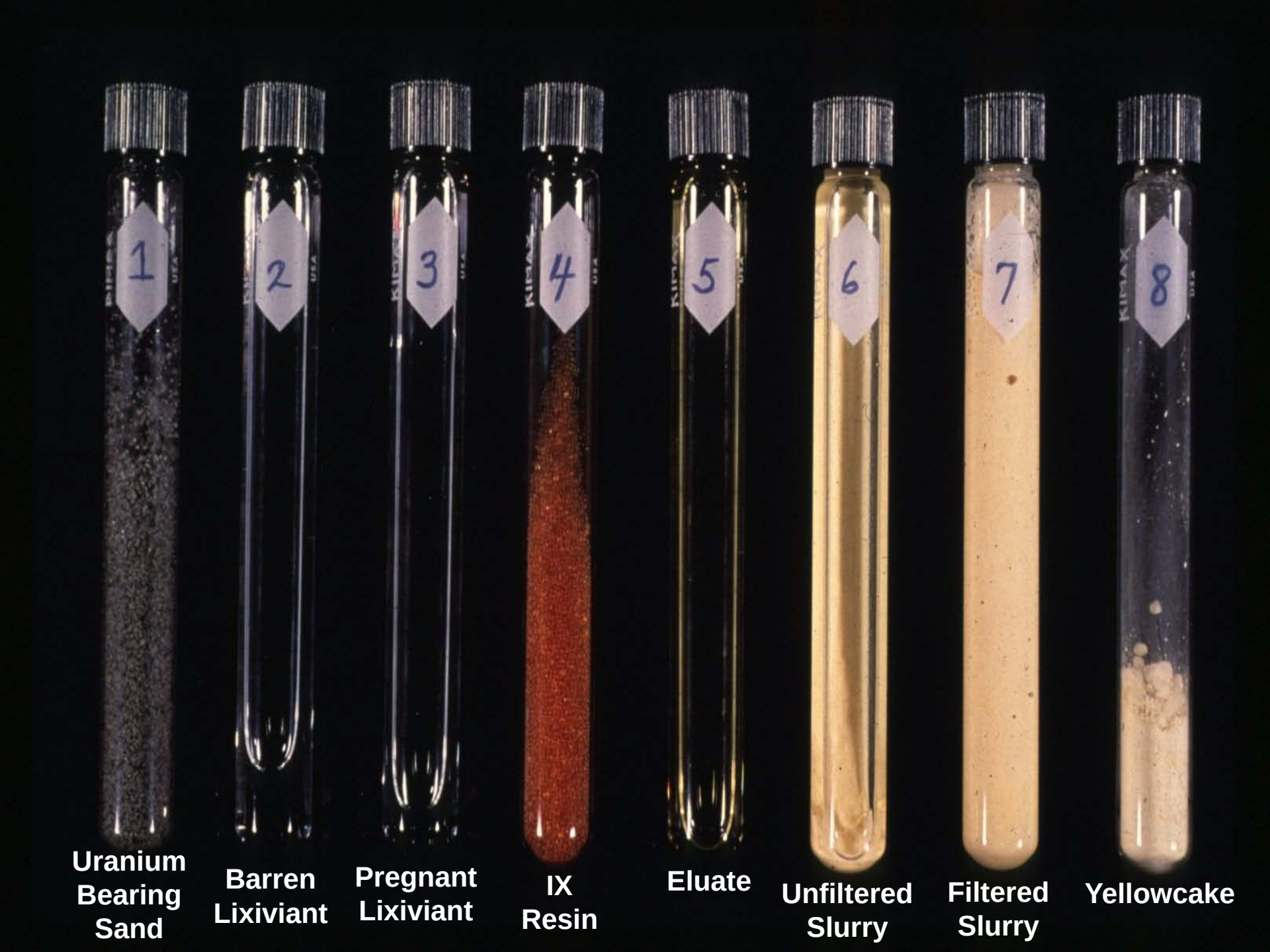
How in-situ leaching works

- **During ISL:**
  - **Ensure that there is a net inflow of clean water into the uranium capture zone from outside. (This measure prevents the injection solution from escaping the capture zone and potentially affecting a nearby aquifer.)**
  - **Continually sample the monitoring wells, local air, and local soils to ensure no significant amount of radioactive material escapes. (This measure prevents any effect on individuals living near the site.)**
- **After ISL is complete:**
  - **Restore the site by removing all radiological hazards and restoring aquifer quality in the now-depleted uranium capture zone back to pre-ISL conditions. This aquifer restoration must meet the technical requirements of the uranium company's UIC permit, which contains a "restoration table" that sets constituent values for the aquifer.**

In-situ Uranium Recovery - Process Flow Diagram



Picture taken from http://www.tceq.state.tx.us/permitting/radmat/uranium/process.html


1
2
3
4
5
6
7
8
Uranium Bearing Sand
Barren Lixiviant
Pregnant Lixiviant
IX Resin
Eluate
Unfiltered Slurry
Filtered Slurry
Yellowcake

UIC Class III well regulations

- **146.32(e) Injection into a USDW, monitoring wells must be completed into the injection zone and any USDW above the injection zone which could be affected by the mineral operation**
  - **These wells will be located in such a fashion as to detect any excursion of injection fluids, process by products, or formation fluids outside the mining area or zone**

UIC Class III well regulations

- **146.32(h) Considerations for the number, location, construction, and frequency of testing monitoring wells:**
  - **Population relying on USDW affected or potentially affected**
  - **Proximity to drinking water wells**
  - **Local geology and hydrology**
  - **Operating pressures and whether a negative pressure gradient is maintained**
  - **Nature and volume of injection fluid, formation fluid, and the process by-products**
  - **Injection well density**

UIC regulations

- **144.12 Cannot conduct injection activities that may contaminate any USDW**
  - **Cannot cause a violation of any primary drinking water regulation**
  - **Cannot adversely affect the health of persons**
- **If any monitoring of USDW indicates contamination of a USDW**
  - **Director shall prescribe additional requirements as necessary to prevent such movement**

Definition of USDW (144.3 and 146.3)

- **An aquifer or its portion:**
  - **Which supplies any public water system (PWS); *or***
  - **Contains a quantity of water *sufficient* to supply a PWS; *and***
    - **Currently supplies drinking water for human consumption; *or***
    - **Contains fewer than 10,000 mg/l TDS; *and***
    - **Is not an exempted aquifer**

What aquifers are exemptible?

- **Definition of an exempted aquifer (146.4)**
  - **An aquifer or its portion that is a USDW, but**
    - **146.4(a) Does not serve as a drinking water source; *and***
    - **146.4(b) *Cannot now and will not in the future serve as a drinking water source*, because:**
      - **(1) It is mineral, hydrocarbon or geothermal energy producing or demonstrated by permit applicant to contain sufficient minerals expected to be commercially producible or**
      - **(2) It is situated at a depth or location which makes recovery of drinking water technically or economically impractical or**
      - **(3) It is so contaminated and could not be treated economically for human consumption or**
      - **(4) It is located above Class III mining area subject to subsidence or collapse *or***
    - **146.4(c) 3,000 mg/l < TDS content < 10,000 mg/l and not expected to supply a PWS**

Definitions

- **USDW: "capable of producing a sufficient quantity of water to supply a public water system"**
  - **1993 memo from Jim Elder, Director of EPA's OGWDW, defined sufficient as:**
    - **One gallon per minute was determined to be sufficient for protection purposes**
- **Public water supply (PWS)**
  - **8/5/98 FR notice revised the definition of a PWS:**
    - **A public water system (PWS) is a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals.**

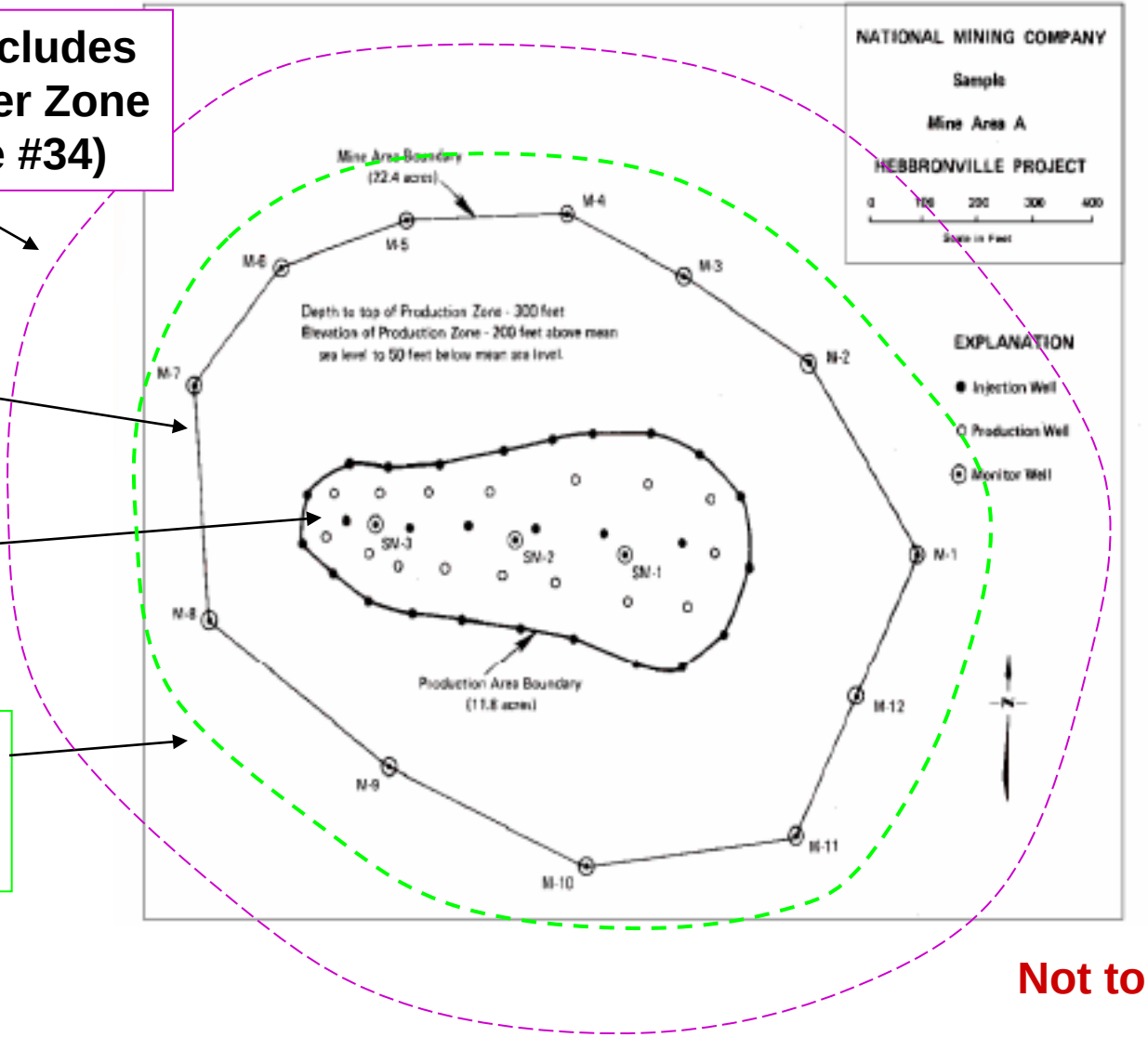
In-situ mining site layout

Extent of AOR (Includes the min ¼ mi Buffer Zone as per Guidance #34)

Monitoring Well Area

Production Area

Aquifer Exemption Boundary



Not to scale

Picture taken from TCEQ production area application for in situ mining of uranium Sep 2009

Well types

- **Production area**
  - **Production wells**
  - **Injection wells**
- **Monitoring wells**
  - **Location**
    - **Above or below within the production area, if appropriate**
    - **Outside area of mineralization and encircle production area**
      - **Monitor different depths as appropriate**
  - **Monitored during mining and restoration**
    - **Requires immediate action should an excursion be observed**

Defining an aquifer exemption area

- **Arial extent and depths**
  - **Production area**
    - **Depth specific depending on ore body depth**
  - **Monitoring well area**
    - **How many wells?**
    - **Depth of wells?**
    - **Where will they be located?**
  - **Excursion zone**
    - **How large?**

General considerations

- Regional geology
- Regional hydrology
- Permit area geology and hydrology
- Direction of ground water flow
  - Topographic maps may be sufficient to determine regional direction of ground water flow in shallow formations
    - Hydraulic gradient can be calculated from topographic map

Site specific considerations

- **Baseline of existing water quality of USDW**
  - **Within ore body**
  - **Outside of the ore body**
  - **Develop restoration tables**
- **Existing wells – any potential pressure sinks?**
  - **Water wells – depths if available**
  - **Other well classes**
- **Potential sources for public water supply**
  - **Ground water intervals and depths**
- **Normal water levels for area**

Excursion zone considerations

- **Pressure buildup**
  - **Check material balance – should not be an issue**
- **Plume movement**
  - **During operations, recovery wells should prevent movement from permitted area**
  - **Monitoring wells would identify any excursion into non-producing zones during operations and during restoration**
  - **Following restoration ground water quality should no longer be a concern**

UIC regulations

- **146.10(a)(4)**
  - **Plug and abandonment plan for Class III aquifer exemption projects must demonstrate adequate protection of USDWs**
  - **Director shall prescribe aquifer cleanup and monitoring where he deems it necessary and feasible to insure adequate protection of USDWs**
- **Level of aquifer cleanup**
  - **Based on approved restoration level**

Post mining ground water restoration

- Ground water quality restoration is based
  - Pre-mining values within the ore body?
  - Pre-mining values outside the ore body?
- Are restoration tables a moving target?
- In many cases, operator cannot achieve the background value so minimum restorations values are amended
  - Public controversy
- Refer back to 144.12 for protection of USDW
  - Injection activities cannot
    - Contaminate any USDW
    - Violate any primary drinking water regulation
    - Adversely affect the health of persons

How do you calculate regional background flow velocity?

- After restoration, there should be no pressure increase from injection activities or density differences. Fluid movement may still occur from a naturally occurring background gradient
- Calculate the ground water velocity:

$$v = -\frac{K \cdot I}{\phi}\ ft/day$$

(Dividing by porosity converts darcy velocity to interstitial velocity)

$$K\left(\frac{ft}{day}\right) = \frac{3.1733 \cdot 10^{-5} \cdot k(darcys) \cdot \rho\left(\frac{g}{cc}\right)}{\mu(cp)}$$

$$I\left(\frac{ft}{ft}\right) = \frac{h_1 - h_2}{L}$$

- Where
  - v = background velocity, ft/day
  - K = hydraulic conductivity, ft/day
  - I = hydraulic gradient, ft/ft
  - Φ = porosity
  - ρ = fluid density
  - μ = fluid viscosity, cp

EPA Guidance No. 34

- **EPA developed technical criteria outlined in Attachment 3 of Guidance #34 since the regulations don't specify technical criteria to judge aquifer exemption requests**
  - **General information**
  - **Specific criteria to evaluate each type of request**
- **EPA approval of aquifer exemption only for specific purposes**
  - **Waste disposal**
  - **Mineral production**
    - **Operators must demonstrate commercial producibility**

Guidance #34: General information

- **Topographic map**
  - Showing boundaries of area to be exempted
- **Description of proposed exempted aquifer**
  - Name of formation of aquifer
  - Subsurface depth or elevation of zone
  - Vertical confinement from other USDWs
  - Thickness of proposed exempted aquifer
  - Area of exemption (e.g., acres, square miles, etc.)
  - Water quality analysis of horizon to be exempted

Guidance #34: General information

- **Investigate that the aquifer does not currently serve as a source of drinking water**
  - **Identify any water supply wells which tap the proposed exempted aquifer within the area of review**
    - **Identify the proposed aquifer exempted boundary on the map**
  - **Gather additional information on wells identified**
    - **For example, depth and completion data, ownership information, purpose for well, volume produced**

Recap

- **What's included in an aquifer exemption?**
  - **Production area**
  - **Monitoring well area**
  - **Buffer zone – not defined in the regs**
    - **R6 defines the buffer zone as the area between the production zone and nonexempt USDW**
    - **WY defines the buffer zone as the area between the production field and the monitor wells**
- **Additional area of review outside the exempted area**
  - **Buffer zone as per Guidance #34**
    - ***Minimum* ¼ mile area of review outside the aquifer exemption boundary**
  - **Any additional area determined necessary**

Discussion items

- **When should baseline ground water samples be obtained?**
  - **No baseline ground water samples taken prior to exploration**
    - **Exploration not regulated by the UIC program**
    - **Potential for contamination prior to ground water samples for restoration table**
- **Should some type of public notice be given of exploration activity?**
  - **Allow public to get baseline data**
  - **Potentially identify contamination specific to exploration or mining activity**

Discussion items

- **Any problems anticipated from pattern changes?**
- **Revoking an aquifer exemption**
  - **Aquifer once again protected so other wells can not tag on to exemption**
    - **R6 exempts aquifers for a specific well class**

Acknowledgements

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- This presentation included slides and information taken from the following UIC inspector training presentations:
  - Class III wells – Brian Graves, R6
  - Aquifer exemptions – Steve Platt, R3

Links

- **TX Commission on Environmental Quality (TCEQ)**
  - **http://www.tceq.state.tx.us/permitting/waste_permits/uic_permits/UIC_Guidance_Class_3.html**
- **RRC of TX – exploration permit**
  - **http://www.rrc.state.tx.us/licenses/smrd/uraniumexploration.php**
- **Wyoming DEQ**
  - **http://deq.state.wy.us/lqd/guidelns/Guide4=3-00.pdf**
- **EPA Guidance No. 34**
  - **http://www.epa.gov/safewater/uic/pdfs/guidance/guide-memo_guidance-34_review_state_prog.pdf**